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EXPLORING THE ORGANISATIONAL EFFECT OF PRENATAL TESTOSTERONE UPON THE SPORTING BRAIN

ABSTRACT

The 2D:4D ratio, a putative marker for prenatal testosterone, has the potential to explain differences in sport performance. To date there has been little research into the association between sporting performance, digit ratio and psychological variables. This study examined the relationship between 2D:4D and mental toughness, optimism, goal orientations, aggression, coping style and their association with sport achievement level. A post facto design was adopted. Participants consisted of an opportunity sample of 122 sports people: male (n =60) and female (n = 62) from a university in North East England. Following informed consent, digit ratio hand scans were measured, using a Vernier Caliper. Questionnaires were then completed which were designed to assess the relevant psychological characteristics: PPI-A (Golby et al., 2007), SMTQ (Sheard et al., 2009), LOT-R (Scheier et al., 1994), Buss-Perry aggression (Buss-Perry, 1992) and 30 item coping style questionnaire (Joseph et al., 1992). MANOVA revealed significant gender differences in digit ratio. Furthermore, 2D:4D was found to differentiate mental toughness scores ($p < 0.001$) and varying levels of sporting performance, which substantiates previous research findings (Manning, 2002). An interpretation could include the proposal that high prenatal levels of testosterone may contribute to the development of increased mental toughness, optimism, ego/task goal orientations in individuals, and hence aptitude towards sport. Findings provide support for the tentative claim that mental toughness may be partially biologically predetermined. Theoretical and practical implications are considered, along with limitations of the current study.

Key words: Digit ratio, sporting performance, mental toughness, coping style, aggression.

INTRODUCTION

Success in sport is determined by marginal psycho-physiological differences. In the pursuit of excellence, adaptive psychological variables are increasingly recognized as important prerequisites to sporting success (Fletcher and Wagstaff, 2009).

Early work on the biological basis of behavior has identified the organizational effects of prenatal testosterone on various adult psycho-physiological parameters (Neave et al., 2003).

A putative marker for exposure to prenatal testosterone is the 2D:4D ratio (Honekopp et al., 2006). Testosterone influences the growth of the ring finger (4D), whereas oestrogen exposure stimulates the growth of the index finger (2D) (Manning, 2002). The ratio of the index finger to the ring finger (2D:4D) has been shown to be a sexually dimorphic trait.

Specifically, males demonstrate a lower ratio, due to increased prenatal testosterone exposure (Manning, 2002). It is suggested that high levels of prenatal testosterone may have a permanent masculinizing effect on human behavior, (Manning, 2002) which could explain the relationship between sporting performance and 2D:4D (Honekopp et al., 2006).

“Masculine” attributes arguably play an important role in sport performance, i.e. aggression. Several sports are negatively related to 2D:4D; these include: football, athletics, skiing, cross country running and general fitness (Manning, 2002; Honekopp et al., 2006). It therefore appears that those exposed to increased levels of prenatal testosterone have greater sporting ability. However, the exclusively male samples included in these studies limit the ability to generalize findings. Only a single study exists in which digit ratio was shown to be negatively associated with females’ endurance running performance (Paul et al., 2006).

This link between digit ratio and sport performance is thought to be multidimensional. Significant associations have been widely noted between physiological parameters (e.g., effective cardiovascular system, physical fitness and visuo-spatial ability) and 2D:4D. Behavioral differences, such as increased exercise frequency, have been identified in those with low 2D:4D, in comparison with high digit ratio (Honekopp et al., 2006). Surprisingly, only one study considers psychological variables in relation to levels of prenatal testosterone exposure. Tester and Campbell (2007) assessed the relationship between 2D:4D, social potency and harm avoidance. Although no significant findings were reported (Tester and Campbell, 2007) this was a welcome direction for research. Since there is scarce research to guide the selection of relevant psychological constructs in relation to 2D:4D and sport, the current study rationalizes the inclusion of the selected variables with reference to their proposed importance in sport performance.

One particular construct that may be deemed important in differentiating athletes' performance is mental toughness (Kuan and Roy, 2007; Golby and Sheard, 2004). The ability to regulate emotion and imagery effectively, display commitment and determination, possess an uncontrollable desire to succeed and an unshakeable confidence, are all characteristic of mentally tough individuals (Crust and Clough, 2005). A further feature of mental toughness is the ability to adapt to stressful conditions. Dealing successfully with competitive stressors requires effective coping strategies. Individuals tend to have a preferred coping style, which can be defined as the individual's tendency to respond and resolve problems with a particular style of action (Bolger, 1990). Three categories of response style: emotion, task and avoidance coping, were identified by Lazarus and Folkman (1984). In exploring the relationship between coping style, optimism and mental toughness, Nicholls et al., (2008) identified a relationship between mental toughness and utilization of more approach coping

strategies and fewer avoidance tactics. Furthermore, an association between mental toughness and optimism was also reported.

Optimism means individuals appraise potential outcomes positively (Burke et al., 2000). It has been proposed that optimism is the most important predictor of sporting achievement in cross country skiers and swimmers (Norlander and Archer, 2002). Several psychological variables associated with sporting success have been related to optimism, including the direction of anxiety interpretation (Wilson et al., 2002). Specifically, athletes with a more optimistic disposition experienced increased facilitative anxiety perceptions (Wilson et al., 2002).

Additionally, an individual's motivation to compete and succeed in sport is important in determining levels of application (Ntoumanis, 2001). One existing motivation theory is the achievement motivation theory (Duda and Hall, 2001) which emphasizes the importance of goal orientation. The model proposes two distinct ego and task orientated goal categories. Duda and Treasure (2001) suggest that performers with adaptive, high task and ego goal orientations are better equipped to meet the demands of sport. Research has suggested that task orientations are of greater benefit to sporting performance, since they promote self-control, regulation (Gano-Overway, 2008) and greater enjoyment (Spray et al., 1999). In an examination of gender differences, Spray, et al. (1999) highlighted the male preference for ego goals and an increased rate of boredom in task orientation conditions.

Aggression serves as the final psychological factor included in this study, and may be positively associated with prenatal testosterone levels (Bailey and Hurd, 2005). In a sporting context, aggression is related to the athletes' tendency to "force action" (Kerr, 2004). Wilson (1983) found that women with low 2D:4D were more assertive and aggressive. Several

studies have shown a negative correlation between aggression and 2D:4D (Bailey and Hurd, 2005). Further evidence is necessary to substantiate this relationship.

This exploratory study was designed to examine the potential of varying levels of prenatal testosterone to differentiate individuals' levels of mental toughness, preference of coping style, optimism, ego and task goal orientations and aggression, which are considered to be important prerequisites of sporting excellence.

METHODOLOGY

Participants

The participants in this study were an opportunity sample of 122 (male=60 and females=62) sports people from a North Eastern university categorized as 18-25 years (n=90) and 25+ years (n=32), from all levels of sporting achievement: International/national (n=23), Regional (n = 43), School/recreational (n= 56).

Participants included competitors from a range of sports, including swimming and climbing, and had between four and thirty years' experience of competition.

Measures

Mental toughness

The Alternative Psychological Performance Inventory (PPI-A; Golby et al., 2007) was used to measure mental toughness. The questionnaire obtains an overall toughness score, and 4 subscale scores: self-belief, determination, positive cognition and visualization. Responses are given on a five point Likert scale, which ranges from 'almost always' to 'almost never'. Collectively satisfying absolute and incremental fit index benchmarks, the inventory possesses satisfactory psychometric properties, with adequate reliability and convergent and discriminant validity (Golby et al., 2007).

The Sport Mental Toughness Questionnaire (SMTQ; Sheard et al., 2008) was used as a secondary measure of mental toughness. The questionnaire yields a total mental toughness figure, and 3 subscale scores: confidence, constancy and control. There is preliminary support for the factor structure, reliability and validity of the measure (Sheard et al., 2008).

Aggression

The Buss-Perry scale (Buss and Perry, 1992) provides an overall value of aggression and four sub-scale measures: Physical aggression (9 items), Verbal aggression (6 items), Anger (6 items) and Hostility (8 items). Statements are rated on a seven point Likert scale, ranging from 'extremely characteristic of me' to 'extremely uncharacteristic of me'. The measure has acceptable psychometric properties (Buss and Perry, 1992) and has been previously administered to sports persons (Lemieux et al., 2002).

Optimism scale

The Revised Life-Orientation Test (Scheier et al., 1994) comprises of three positive items, three negative items and four filler items. Statements are rated on a five point Likert scale, ranging from 'strongly agree' to 'strongly disagree'. Scores range from 6-30, with a greater

score representing higher optimism. Studies have shown the LOT-R to have acceptable validity and internal consistency (Smith, 2003). It is also appropriate in the assessment of athletes (Czech et al., 2002).

Coping strategies

Joseph et al. (1992) selected thirty coping style items, which were also used in this study. Style can be grouped into three categories: emotion (10 items), problem (10 items) and avoidance coping (10 items) (Endler and Parker, 1990). Statements are rated on a four point Likert scale, ranging from 'I do this a lot' to 'I never do this'. The score for each conceptual grouping can range from 10 to 40; overall scores ranging from 30 to 120. Psychometric properties of this measure are adequate (Joseph et al., 1992). Support is given to the utilization of this tool with competitive athletes (Nicholls et al., 2008).

Goal orientations

The Task and Ego Orientation in Sport Questionnaire (Duda and Nicholls, 1992) contains thirteen items: six indicating ego orientation and seven showing a task orientation. Items were rated on a five point Likert scale, ranging from 'strongly agree' to 'strongly disagree'. Scores for ego orientation range from 6 to 30 and task orientation range from 7 to 35. The validity and internal reliability of this measure are deemed adequate (Ebbeck and Becker, 1994).

Digit ratio measurement

Digit ratio was measured using Vernier Calipers (Fink et al., 2006). It was grouped into low (n = 61) and high (n = 61) categories. Mean digit ratio for males is 0.96 (Manning, 2002), standard deviation is 0.04. Low group (0.90-0.96); which is one and a half standard

deviations below the mean. High group (0.96-1.04); which is two standard deviations above the mean.

Procedure

Following approval from the University Ethics Committee, requirements of the study were explained to participants before they gave signed consent to take part in the research. The confidentiality of results was explained to participants, who then completed the battery of questionnaires. They were finally required to provide a digital hand scan of both hands, which were computed using Vernier Calipers (Fink et al., 2006).

Data analyses

To explore the nature of the relationship between 2D:4D digit ratio and psychological variables, digit ratio was dichotomised using a mean split. Sport achievement level digit ratio group differences for each measured psychological characteristic were explored using a multivariate analysis of variance (MANOVA). Alpha was set at 0.05.

Recent studies have been criticized for including several measures of digit ratio within a single analysis (left/right hand), as it increases the probability of type 1 error. Whilst the current research acknowledges this argument, Bonferroni correction compensates for this potential error. For the post-hoc tests, significance was set at $p < 0.025$.

RESULTS

Means and standard deviations of all measured variables displaying significant effects are presented in table 1. There was a significant multivariate effect for right hand digit ratio, Wilks $\lambda = 0.581$, $F(1, 121) = 4.04$, $P < 0.001$, partial $\eta^2 = 0.419$, with significant differences observed in eleven of the seventeen dependant variables. **INTERPRET EFFECT SIZES**

Specifically, there were significant group differences in: *determination* $F(1, 121) = 23.22$, $P < 0.001$, partial $\eta^2 = 0.162$; *self-belief* $F(1, 121) = 20.75$, $P < 0.001$, partial $\eta^2 = 0.147$; *positive cognition* $F(1, 121) = 34.72$ $P < 0.001$, partial $\eta^2 = 0.224$; *visualization* $F(1, 121) = 44.55$ $P < 0.001$, partial $\eta^2 = 0.271$; *confidence* $F(1, 121) = 17.68$ $P < 0.001$, partial $\eta^2 = 0.128$; *constancy* $F(1, 121) = 7.604$ $P < 0.01$, partial $\eta^2 = 0.060$; *control* $F(1, 121) = 18.069$ $P < 0.001$, partial $\eta^2 = 0.131$; *optimism* $F(1, 121) = 9.989$ $P < 0.01$, partial $\eta^2 = 0.077$; *ego goal orientation* $F(1, 121) = 4.013$ $P < 0.05$, partial $\eta^2 = 0.032$; *task goal orientation* $F(1, 121) = 9.654$ $P < 0.01$, partial $\eta^2 = 0.074$ where those with a lower digit ratio scored higher than those with high 2D:4D. A significant group difference was located in relation to *hostility* $F(1, 121) = 15.095$ $P < 0.001$, partial $\eta^2 = 0.112$, where those with high 2D:4D reported significantly greater levels.

There was a significant multivariate effect for left hand digit ratio, Wilks $\lambda = 0.522$, $F(1, 121) = 3.98$, $P < 0.001$, partial $\eta^2 = 0.388$. All significant effects shown for right hand are identical for left hand ratio.

There was a significant multivariate effect for sporting level achievement, Wilks $\lambda = 0.00$, $F(1, 121) = 3.505$, $p < 0.001$, partial $\eta^2 = 0.366$, with significant differences observed in 15 of the dependant variables. Means and standard deviations of all variables displaying significant findings are contained in table 2, and post-hoc analysis is presented in table 3. Discriminant analysis revealed that visualization and hostility best predicted digit ratio group membership (see table 4 for a summary).

CONCLUSION

This study aimed to establish the relationship between 2D:4D and several psychological variables, selected for their relevance to sporting success. It is the first study, within this domain, to focus on this particular combination of variables and to utilize a sample of mixed gender. Sexual dimorphism was observed in digit ratio, as expected (Manning, 2002), with males demonstrating lower values.

The main findings substantiate previous research, which recognizes the sporting ability and 2D:4D relationship: those with high prenatal testosterone exposure possess greater aptitude within sport (Manning, 2002; Manning and Taylor, 2001; Honekopp et al., 2006). This difference was significant when comparing the highest (international/national) and lowest (leisure/school) groups; perhaps there is a threshold for prenatal testosterone's influence upon sporting ability. The psychological differences identified among performers, competing at different sporting levels in this study, may illuminate the nature of this relationship.

Athletes participating in the lower level of sporting achievement, selected emotion focused coping as the preferred style, significantly more than regional level individuals. They also reported lower levels of the subcomponents of mental toughness, including: self-belief, confidence and positive cognition. Research has suggested that a greater level of self-confidence is associated with an increased sense of influence over one's life outcomes. This sense of empowerment, coupled with increased positive cognition, could relate to higher levels of emotional stability (Gucciardi et al., 2008). This would indicate less use of emotion

focused strategies, which is characteristic of the mentally tough person. This study's conclusions concur with previous research, proposing that approach focused coping is psychologically adaptive and used by mentally tough, high performing individuals in sport (Nicholls et al., 2008). Despite this, no differences were identified in individuals' use of avoidance and approach coping strategies. Perhaps the unique ability of mentally tough, high performing individuals is in their appropriate, varied selection of coping strategies according to the stressor presented at that time. Future research may wish to address this claim.

It was also revealed that those competing at an international/national standard and with low 2D:4D scored significantly higher than those competing at all lower levels and with high 2D:4D. Perhaps those competing at an elite level are likely to be frequently exposed to visualization and imagery techniques (MacIntyre and Moran, 2007). They may possess greater determination, because of the enhanced work ethic necessary to succeed (Holland et al., 2010). Furthermore, the competitive nature of sport and constant performance comparison among athletes is likely to increase the use of ego goals (Stornes and Ommundsen, 2004). Significant differences were also identified in other mental toughness subcomponents. Specifically, those competing at higher levels (international/national) and with low 2D:4D scored higher on the subscales of control (SMTQ), confidence (SMTQ), self-belief (PPI-A) and constancy. This provides further support for the claim that these characteristics are important in sport performance (Gucciardi et al., 2008; Crust, 2007; Golby and Sheard, 2004), and also highlights the potential of prenatal testosterone in partially explaining their development.

Furthermore, those with a low digit ratio scored significantly higher on the optimism scale.

Level of sport? Researchers have suggested that optimism level may be an important factor in determining the level of effort invested to achieve goals (Nicholls et al., 2008) and is a significant predictor of success in cross country skiing (Norlander and Archer, 2002).

Interestingly, this study's findings in relation to aggression appear incongruent with previous 2D:4D research. Several studies had noted a negative relationship between all subscales of aggression and 2D:4D (Bailey and Hurd, 2005). The current study found that individuals with low 2D:4D and currently competing in higher levels of sporting achievement, reported significantly lower hostility. This appears to make sense when considering hostility in relation to sport: hostility was previously shown to be positively related to risk of injury (Galambos et al., 2005) and negatively associated with the number of training hours undertaken in martial arts (Daniels and Thornton, 1992). Further research may wish to explore the exact mechanisms underlying this relationship.

The current study serves as preliminary research into the associations between 2D:4D and several psychological characteristics thought to be related to successful sporting achievement. Present findings highlight the scope for future research in this area, along with the measured proposal that prenatal testosterone exposure may partially explain adult sporting success. The possibility of talent selection based on digit ratio, although potentially plagued with ethical concern, highlights the need to further explore this relationship. Additionally, the possibility of developing objective biological measures, such as 2D:4D ratio, to support self-reported measures of assessment, could significantly advance issues with measurement validity and reliability (Chalabaev et al., 2009). This topic is particularly relevant with some of the selected scales utilized in this study. The existing mental toughness measurement (Crust, 2008) and the Task and Ego Goal Orientation in Sport Questionnaire (Lane et al., 2005) have been subject to criticism. Perhaps future research may wish to employ sound existing psychometric measurements, in order to substantiate the relationship between prenatal testosterone (2D:4D) and psychological variables relevant to sport. A further noted limitation of the current study includes its heterogeneous sample; addressing similar research questions within specific sports and level may provide a more detailed insight.

- **KEY POINTS**

- Increased prenatal testosterone exposure may be associated with successful sport performance.
- There is a need to consider psychological aspects related to sport performance and their relationship with 2D:4D.
- Mental toughness variables, optimism, goal orientation, hostility and coping style are related to levels of prenatal testosterone.
- Perhaps with further substantiation, 2D:4D could provide a supporting objective measure, to complement existing psychometric instruments.

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Publications

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